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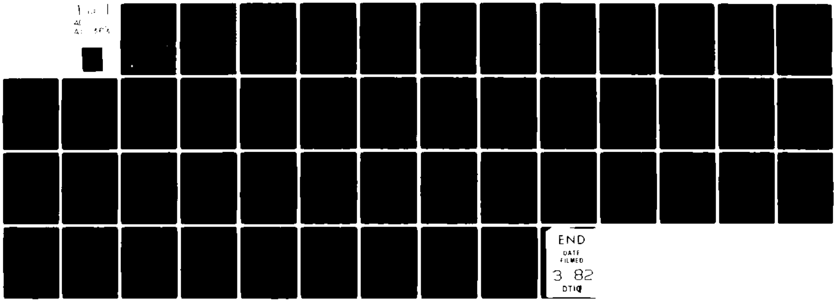

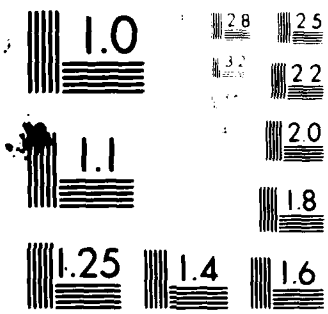

MICROCOPY RESOLUTION TEST CHART

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A VIDEO PULSE RADAR SYSTEM FOR TUNNEL DETECTION

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A video pulse radar system using a microcomputer-controlled data acquisition system is described which allows remote site recording of video pulse radar waveforms. Proper setup of the digital and analog hardware is presented and the functions provided by the firmware program are explained. The operation of the system is detailed along with recommendations concerning data collecting techniques.

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Letter on file

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I. INTRODUCTION

A video pulse radar system using a microcomputer controlled data acquisition system is described in this report. This portable system converts video pulse radar returns into a numerical representation which is stored on a digital tape recorder. The use of a microcomputer provides capability for limited preprocessing of the data in the field. In the present implementation, ensemble waveform averaging is the extent of the digital preprocessing. The bulk of the waveform analysis is intended to be performed on a more powerful remote computer, which obtains the waveforms by reading the microcomputer generated magnetic tapes.

The first two sections present the setup of the analog portion of the system and provide recommendations for a meaningful data collecting procedure. The next three sections detail the required interconnections between analog and digital systems, outline the capabilities of the microcomputer firmware, and describe the digital tape recorder. Finally, a sample waveform recording sequence as might be performed in the field is included.

II. SETUP OF THE ANALOG SYSTEM

The analog portion of the data collection system can be set up, checked out, and utilized independently from the microcomputer system.

The following discussion pertains to the use of a sampling oscilloscope with the HFW systems (Terrascan, BANT, and LBANT[1,2]) and the 6 ns pulser. The use of the LBFA antenna with the Hewlett Packard pulse generator, is detailed in another report[3].

The sampling oscilloscope performs the scaling of broadband time domain radar echoes (up to 1 GHz for this system) into low frequency (audio range) sampled replicas. This low frequency waveform is displayed on the oscilloscope screen. In the current application, the replica is also digitized by conventional analog to digital converters which are part of a microcomputer system.

The equipment associated with the sampling oscilloscope includes a 7844 dual beam mainframe, a 7S12 sampling system plug-in, a 7A22 differential amplifier plug-in, and a 7B50A timebase. Accessories of the 7S12 include

An S5 sampling head (rise time = 1 nsec),

An S-53 trigger recognizer, and an S-52 step generator.

To prepare the oscilloscope for use as a sampling receiver, the oscilloscope controls should be set as follows:

Beam Controls

Beam 1: Vertical mode - Left
Horizontal mode - B

Beam 2: Vertical mode - Right
Horizontal mode - A

B trigger source: Left

7A22 Differential Amplifier

Volts/Div: 1 Volt

HF - 3 dB Point: 1 MHz
LF - 3 dB Point: DC

+input port: DC
-input port: GND

7S12 Sampling Unit
Volts/Div: 100 mV with mV button depressed

Time-Distance: x1
Time/Div: 50 ns

Scan Knob: midrange
Scan Mode: REP

Use a 50 ohm termination unit on the input of the S-5 sampling head.

S-5 Coupling Switch: DC
S-53 Slope Switch: (+)

7B50A Timebase

Time/Div: 1 msec
Magnifier: x1

Triggering Controls:
Slope: (-)
Mode: Auto or Norm
Coupling: AC LF REJ
Source: INT

To make use of the waveform sampling capability, antennas and pulser are connected as shown in Figure 1. The Microlab FXR HZ-10N capacitive trigger pickoff unit is connected in series with the transmitting signal line from the Terrascan package pulse tube. The capacitive pickoff

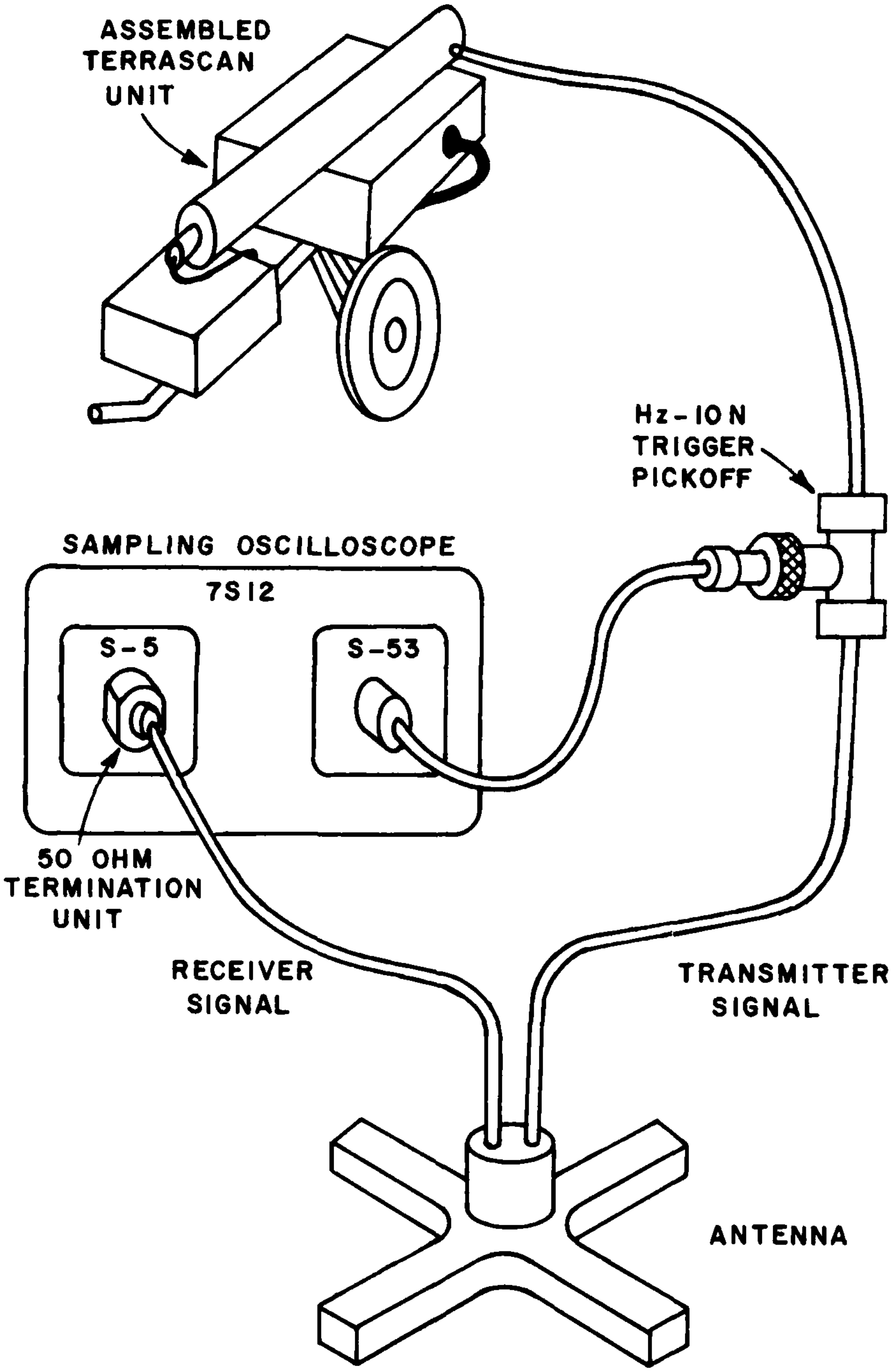

Figure 1. Antenna and pulser interconnections for use with the analog sampling system.

is generally placed as near to the pulse source as is possible, which in this case is directly on the end of the coaxial cable emerging from the Terrascan pulse tube. A TNC male to N male adapter will be necessary. The variable depth capacitive probe should initially be set about midway in its range of positions.

A short length of cable is then used to connect the capacitively coupled trigger to the S-53 trigger recognizer.

The transmitter pulse, after passing through the capacitive pickoff, is routed to the transmitting antenna using RG-9/U cable. Physically the two dipoles in each crossed pair are identical and either may be selected as the transmitting antenna. The receiving antenna is then connected via RG-9/U cable through a 50 ohm termination unit and into the S-5 sampling head. Because of internal delays in the oscilloscope, the minimum length of cable which can be used between the trigger pickoff and the S-5 sampling head is approximately 40 feet.

Care should be taken to guide the cables which are connected at the antenna upwards, perpendicular to the ground, for several feet. They should then be lead away in such a manner that they do not drape back down to the ground until they are several feet beyond the antenna tips. This is necessary to preserve symmetry (and consequently transmit/receive isolation) in the antenna region. When using the Terrascan antenna, this is nicely accomplished by the metal handle which is included with the antenna. For other antennas a wooden tripod, such as that used by a surveyor's transit, has been employed for this purpose. Once it has been verified that the system is set up as described above, the pulse generator may be powered up by turning on the Terrascan unit. The level and stability controls on the S-53 trigger recognizer are now adjusted to provide a stable picture of the received waveform on the oscilloscope screen (Beam 2). If the trace is free-running (not triggering) it will appear as a solid line. When proper triggering is occurring, the trace will appear

as a dotted line. Readjusting the capacitive pickoff may be deemed necessary. The capacitive pickoff should be pushed in only as far as is needed to provide a stable oscilloscope trace. Pushing the pickoff in all the way has the potential for burning out the S-53 unit. When the system has been set up properly and the intended equipment settings obtained, the control of the oscilloscope sweep may be turned over to the data acquisition microcomputer, as detailed in a later section.

III. DATA COLLECTION TECHNIQUES

A common problem encountered in remote data collecting occurs when the waveforms are finally being examined and it is found that a certain important equipment setting was not recorded or a definitive experiment was overlooked. It is taken for granted that the equipment settings, cables, antenna, and pulser used will be recorded in some way for each waveform. The discussions which follow are intended to detail methods which may be used to alleviate certain of the more basic oversights.

One of the most important pieces of information to be obtained from a recorded waveform is the relative time delay to a feature of interest (target echo). This relative delay corresponds to a signal path from the transmitting antenna to the target and back to the receiving antenna. The time at which the transmitter energy reaches the antenna feedpoint marks 'time zero' (tØ), corresponding to the surface of the ground. A cross-coupled pulse usually appears at this time. Time delays of subterranian echoes should be measured from this 'time zero' to allow accurate determination of depth. Since this time reference is so important it is often useful to set the oscilloscope range window to include the initial coupled pulse at tØ, even though targets near the surface may not be of interest.

Certain antenna and pulser combinations may not provide a noticeable pulse at tØ. To aid in identifying this time, a wire several feet long may be placed bisecting the feed region of the crossed dipoles. This should give rise to a strong ringing signal which will begin at tØ. It is usually convenient to position tØ one division from the left edge of the oscilloscope screen.

Even if the desired time window for recording does not include tØ, a recording should be taken which does include it. It is felt that if precise delay measurements are needed, there is too much backlash in the oscilloscope mechanical delay control to rely solely on its readings. If this is the case, after recording the tØ waveform the oscilloscope delay knob may be cranked out so that the last few centimeters (right hand side) of the first recording have now become the first few centimeters (left hand side) on the oscilloscope screen. This display should now be recorded and the process repeated until the desired time window is reached. The overlapping preliminary recordings may later by pieced together, allowing a precise determination to be made of the actual delay to any feature appearing in the waveform set which was recorded in the desired time window.

Another common problem encountered in data collection occurs when clutter is present in an early portion of the waveform which is much stronger than the expected signal echo (which occurs in a later part of the waveform). The dilemma is that when the oscilloscope gain is adjusted to provide an unclipped view of the clutter, very poor resolution is obtained for the weak target echo. The resolution limit is related to the quantization level of the 8 bit A/D converter of the recording system. On the other hand, if the oscilloscope gain is set to provide a reasonable presentation of a target echo, the clutter filled early portion of the waveform will be driven off screen, clipping the recorded waveform. This clipping may be acceptable in some instances, but for many types of data

processing the clipping causes erroneous results. Spectral analysis, filtering, and analysis in the complex frequency plane all may provide misleading information if clipped waveforms are used.

The present solution to this problem is to record the waveform twice, once on each gain setting. Then the two waveforms may be combined using a computer with more numerical precision. This allows the weak target echo to be represented with the same precision as the strong clutter signal. A more satisfying solution would be to incorporate a tapered gain function in the oscilloscope amplifiers, automatically increasing the front-end amplification as the later time portions of the waveform are being sampled. Unfortunately such a function has not been included in the present system.

IV. SETUP OF MICROCOMPUTER SYSTEM

The Microcomputer Data Acquisition System (MIDAS) allows controlling of the sampling process and converts the sampled radar signals into a digital format. This eliminates the need for bulky and expensive multichannel analog recorders. The microcomputer consists of an Intel SDK-80 computer board, an 8 K byte memory board, and a board containing keypad, display and analog I/O. The heart of the computer is an Intel 8080 microprocessor.

The equipment associated with the data acquisition computer includes the microcomputer box, the microcomputer power unit, and a Tektronix 4923 Digital Cartridge tape recorder. These items are assembled as shown in Figure 2. Be certain that Pin 1 on each 'harmonic' connector on the recorder cable matches with the designated Pin 1 on the microcomputer box. Improper connection may damage the recorder.

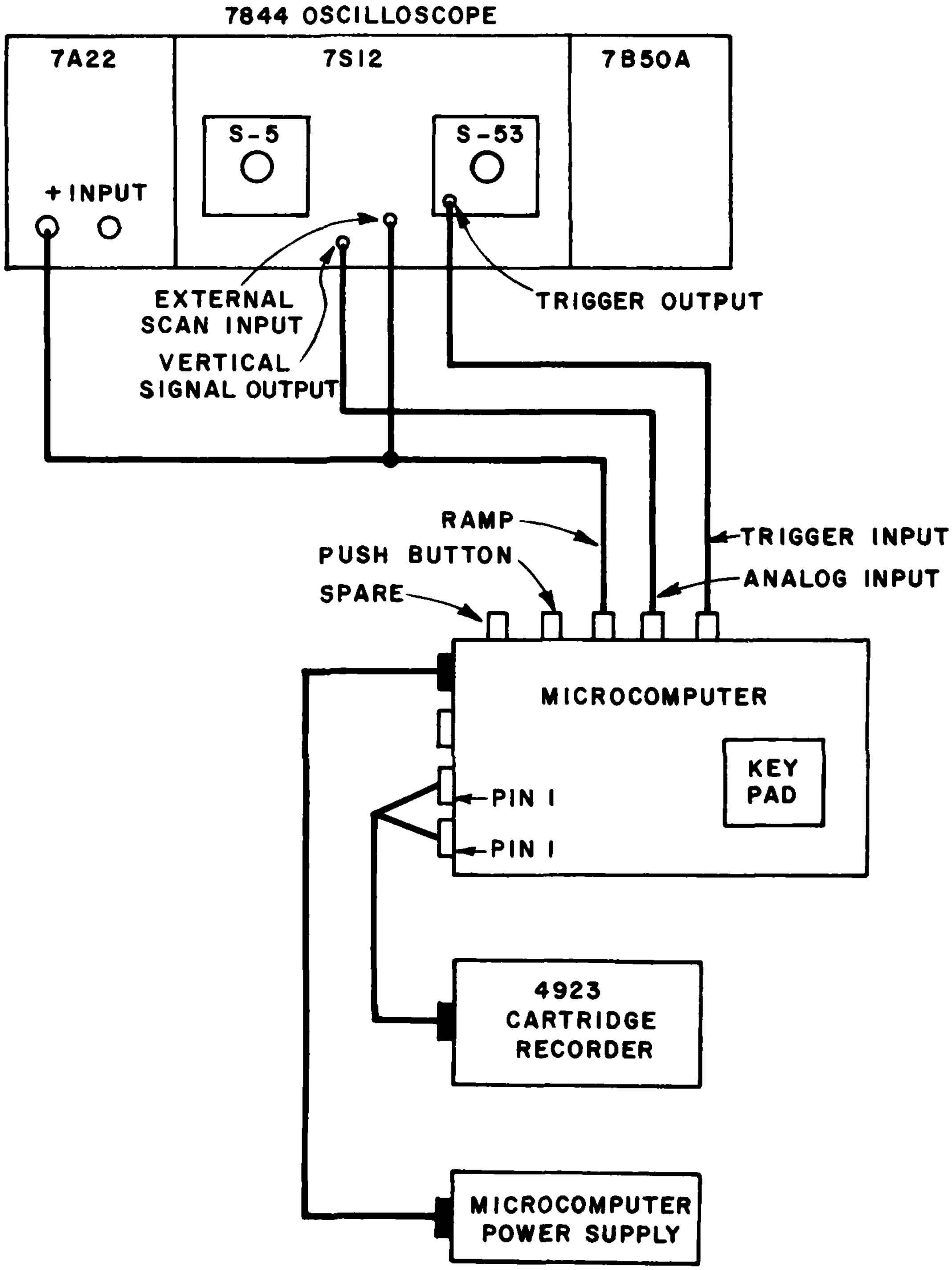

Figure 2. Interconnection of the sampling oscilloscope and the microcomputer system.

The connections which must be made between the microcomputer unit and the 7844 oscilloscope are illustrated in Figure 2. A specific description of each interconnection follows.

1. A coaxial cable with a BNC male fitting at one end and a BSM connector at the other is used to connect the 'trigger out' signal of the S-53 trigger recognizer to the trigger jack (Port F) on the microcomputer box. This signal provides the computer with interrupts, which synchronize certain computer functions with the firing of the pulse generator.

2. A coaxial cable with a BNC male plug at one end and pin plugs at the other is used to connect the vertical signal out of the 7S12 to the signal in jack (Port G) of the microcomputer box. The signal wire is the red wire. The black wire (ground) should be fastened to the grounding terminal on the 7A22 plug-in. This signal is the sampled waveform which is to be digitized by the A/D converter.

3. A coaxial cable with a BNC male plug at one end and pin plugs at the other is used to connect the ramp (Port H) from the computer box to the input ramp pin jack of the 7S12. The red wire is the signal wire. Connect the black (ground) pin plug to the pin jack of the grounded wire from step 2. This signal is used to drive the horizontal amplifiers of the oscilloscope which also determines the time delay of the sampling point. To utilize this signal properly, the external input push button on the 7S12 should be depressed and the scan vernier knob turned fully clockwise.

4. A coaxial cable with a BNC male plug at one end and pin plugs at the other is used to connect the (+) input of the 7A22 differential amplifier plug-in to the ramp signal of step 3. This

is done by piggybacking this red pin plug into the red pin plug which is in the 'input ramp' pin jack on the 7S12. When the computer is in the waveform display mode the ramp line is used to send an analog waveform to the oscilloscope on Beam 1. The volts/div switch of the 7A22 should be set at 1 v and the 7B50A time base should be set for 1 ms/div.

Upon powering up the microcomputer system an audible 'beep' will be heard and the Light Emitting Diode (LED) display will read all zeroes indicating that the computer program is idling in the command loop. The digital recorder power should be turned on after the computer itself. If analog and digital systems have been interconnected as previously described, the computer keypad may be now used to control the data acquisition and associated processes.

V. COMPUTER FIRMWARE FUNCTIONS

A summary of the keypress functions is given below. Their use is described in the following paragraphs.

Ø....Record a waveform from the sampling oscilloscope into the computer memory.

1.... Initiate remote pushbutton waveform recording sequence.

2....Enter two digit sequence number for next waveform.

3....No control function.

4....Select number of points desired per waveform (16,32,64,128, or 256).

5....No control function.

6....Select number of averages to be taken for each data point (0, 2, 4, 8, 16, or 32).

7....Enter tuneup mode which sweeps oscilloscope and displays on the LED's, the average value, peak value, and peak position of the digitized waveform.

8....Enable a program branch to a user supplied PROM.

A....Display a selected waveform from the computer memory on the oscilloscope.

B....Dump waveform data from computer memory to digital cartridge recorder.

C....No control function. Used to return to command loop from certain functions.

D....Read and verify waveform data from digital cartridge recorder against computer memory.

E....Turn off alarm which results when computer memory is full of waveforms or when a read/verify tape error has occurred.

F....Restart and re-initialize program.

The operation of these functions is now explained in detail.

(Ø) Record a waveform

Pressing key Ø while in the command loop initiates the recording of a waveform from the sampling oscilloscope. The center two LED's

display the sequence number for the waveform being recorded. The waveform is stored in the next available memory area and pertinent pointers are advanced. The memory is checked before recording commences and if the memory is full an alarm is set off (see keypress E). Otherwise the program returns to the command loop.

(1) Initiate remote pushbutton recording sequence

Pressing key 1 while in the command loop allows recording of successive waveforms to be controlled remotely, via a pushbutton. Each pressing of the pushbutton causes one waveform to be recorded into the computer memory (see keypress Ø). To return to the program command loop press key C. This is an optional feature for user convenience and the pushbutton hardware has not been included with this system. The pushbutton cable is to be connected to BNC jack I on the computer chassis. When depressed, the button should short the cable center conductor to the shield (ground).

(2) Enter sequence number.

Stored with each waveform is a two digit sequence number which is to be used with written records to identify each waveform. Upon startup or reset, the sequence number is initialized to ØØ. As each waveform is recorded this sequence number is incremented up to FF (hexadecimal) after which it starts over at ØØ again. The sequence number for the next waveform may be changed at any time by the user by pressing key 2 while in the command loop. At this point a 2 is displayed in the leftmost LED and the next two keypresses will select the new sequence number. The program is then returned to the command loop, but the new number is not displayed until the next recording operation.

(4) Select number of points per waveform.

Upon startup or reset the number of data points per recorded waveform is initialized to be 256. This may be changed by pressing key 4

while in the command loop. At this point a 4 is displayed in the left most LED and the next keypress will select the number of data points to be recorded as follows:

Key press	Selects
Ø	16 points
1	32 points
2	64 points
3	128 points
4	256 points

Keypresses other than Ø through 4 are ignored and the program waits for a valid entry. After a valid keypress the program returns to the command loop.

This feature was included for added flexibility.

Important note: If the number of data points per waveform is to be changed in the middle of a recording session, dump any waveforms remaining in memory onto the digital cartridge recorder (see keypress B). Having waveforms of differing lengths in memory may cause the waveform display feature (keypress A) to malfunction.

(6) Select number of waveform averages.

Upon startup or reset the number of averages taken per data point is initialized to 4. During data recording, each of the horizontal positions of the waveform (time positions) is sampled 4 consecutive times and the computed average value is stored in the proper cell of the memory area. The number of averages to be taken may be changed at any time by pressing key 6 while in the command loop. At this point a 6 is displayed

in the leftmost LED and the next keypress will select the number of averages to be taken per data point as follows:

Keypress	Selects
Ø	no averaging
1	2 averages
2	4 averages
3	8 averages
4	16 averages
5	32 averages

Key presses other than Ø through 5 are ignored and the program waits for a valid entry. After a valid keypress the program returns to the command loop.

(5) Enter tuneup mode

Pressing key 7 while in the command loop transfers program control into a 'tuneup' mode which allows computer controlled sweeping of the oscilloscope without recording a waveform and also verifies proper operation of the A/D and D/A converters. When in the tuneup mode the oscilloscope is swept continuously, employing the number of points per waveform and the number of averages per data point which have been selected. The incoming radar return should appear on the oscilloscope screen. The two leftmost LED's display the peak signal amplitude as a two digit hexadecimal number. The A/D converter output ranges from Ø below the bottom of the oscilloscope screen to FF above the top of the screen. The amplitude value which is displayed is that of the waveform element which is farthest from midscale (midscale=4Ø Hex) either above or below. The center two LED's display the time position of this peak as a two digit hexadecimal number. This number corresponds to the element number of the peak which ranges from ØØ at the left edge of the oscilloscope screen

to FF at the right edge of the screen. The rightmost two LED's display the computed average value of the waveform as a two digit hexadecimal number. As with the peak amplitude, this value may range from ØØ to FF.

To exit the tuneup mode, press key C.

(8) Branch to user ROM

User defined functions may be added to the computer without modifying the main program. These functions may be programmed into 2708 Erasable Programmable Read Only Memories (EPROM's) for use in hardware slots 'ROM 2' and 'ROM 3'.

To cause a jump from the main program to a user routine Key 8 is pressed while in the command loop. At this point an 8 is displayed in the leftmost LED and the next keypress will select the ROM position to which program control is transferred. Pressing Key 2 or 3 transfers control to ROM 2 (address 8ØØ Hex) or ROM 3 (address CØØ Hex). Pressing Key Ø selects the main program (ROM Ø) and is equivalent to a software reset (see keypress F). If any key other than Ø, 2, or 3 is pressed the program returns to the command loop.

(A) Display a stored waveform.

To display a previously stored waveform on the oscilloscope, key A is pressed while in the command loop. At this point an A is displayed in the leftmost LED and the next two keypresses select the sequence number (see Key 2) of the stored waveform to be displayed. If no waveform is found with the given sequence number, the program returns to the command loop. If a waveform is found, the sequence number is displayed in the leftmost two LED's. The waveform data is now being continuously cycled out of the D/A port to the oscilloscope. Turn down the intensity of beam 2 and turn up the intensity of Beam 1 on the 7844 oscilloscope. Now the

timebase and triggering controls of the 7B50A plug-in should be adjusted to provide a stable picture on the oscilloscope screen. (A plus to minus full scale pulse is inserted at the beginning of each cycle of the waveform data to provide a convenient trigger signal for the oscilloscope.)

To terminate the waveform display press Key C and the program will return to the command loop. To prepare for further waveform recording, turn down Beam 1 and turn up Beam 2 on the oscilloscope.

(B) Dump waveform data to cartridge recorder.

When the digital cartridge recorder is set in its write mode (see section on the cartridge recorder) and the computer is in the command loop, pressing Key B causes the waveforms stored in computer memory to be copied to the digital recorder. This waveform dumping process may be performed whether the memory is full or only partially full of waveforms; only the portion of memory containing waveform data is dumped. When the dump is completed, program control is returned to the command loop. At this point the STOP button on the recorder should be pressed in order to make each tape dump a complete logical file, as defined by the recorder. This is done to make waveform recovery from the tape more convenient. This is also required if the read/verify function of the computer (Key D) is to be used. If the indicator light over the recorder STOP button is lighted before you press the STOP button, this means the tape has no more room. This dump is probably incomplete (use Key D to check) and memory should be redumped on a fresh tape.

Waveform dumping of a given memory content may be performed any number of times (to provide redundant recordings if desired) until a new waveform is recorded via Key Ø or Key 1. When the first new waveform is recorded after dumping the memory, the software data pointers are reset and reference to the previous waveforms is lost. The sequence number is not reset, and continues in sequence.

(C) Return to command loop

Pressing Key C causes program control to return to the command loop when in the following operations

1) push button recording mode (Key 1)

2) Tuneup mode (Key 7)

3) Waveform display mode (Key A)

Key C may also be used as a convenient invalid character to abort the 'jump to user PROM' routine (Key 8). Control is returned to the command loop (see Key 8).

(D) Read and verify cartridge tape

After pressing Key B to copy the memory to tape it may be desirable to verify that the recording is accurate. This may be done if the memory dump constituted a complete tape file (as recommended in the Key B section). If the last dump was structured as only part of a file, the Key D read verify routine will not work properly. If the dump does constitute a complete file, the tape should then be rewound to the beginning of this file by a momentary press of the recorder's REVERSE button, and prepared for the read by pressing the RUN button. Pressing Key D on the computer while in the command loop will initiate a byte by byte comparison of the tape contents with the memory contents. If an error is encountered the alarm is set off. Pressing Key E will silence the alarm and return program control to the command loop, from where another tape write operation (Key B) may be tried. The STOP and then the REVERSE button on the recorder should be pressed to position the tape for another write attempt. If the tape data is valid, program control is returned

to the command loop. To prepare the recorder for further data recording press the STOP and then the FORWARD button on the recorder.

(E) Silence Alarm

Key E is pressed to silence the alarm which occurs when the computer memory is full of waveforms (in recording modes, Keys Ø or 1) or when a read/verify tape error is encountered (in tape check mode, Key D). Control is returned to the command loop.

(F) Software reset

Pressing Key F while in the command loop causes a branch to the beginning of the computer program. This resets all pointers and reinitializes all default values. This is equivalent to pressing the reset button on the SDK-80 computer card.

VI. THE DIGITAL CARTRIDGE TAPE RECORDER

This section briefly describes the digital recorder functions which are necessary to operate the recorder with the microcomputer data acquisition system. A more complete description of the recorder features may be found in the Tektronix 4923 Digital Cartridge Tape Recorder Users' Manual.

To insure that the internal circuitry of the 4923 recorder is properly initialized, the recorder should only be turned on after the main microcomputer data system has been powered up. (The microcomputer system provides the clock necessary for operation of the 4923 recorder.) Next, verify that the Test/Operate switch on the back of the recorder is in the operate position and the BINARY button on the front panel is depressed.

Read Operations

When the digital cartridge is inserted and the recorder is in a stopped condition, the Read Mode may be entered by a momentary press of the RUN button. The READ indicator (above the RUN button) will become lit. The microcomputer may then read data a byte (eight bits) at a time from the recorder's tape buffer. When a File Read Operation is complete, the STOP and then the FORWARD button should be pressed to position the tape for a read or write on the next file.

Write Operations

A Write Operation is used to write data onto the tape from the microcomputer. To enter Write Mode, press in and hold the WRITE button and simultaneously press the RUN button. The WRITE indicator (above the WRITE button) will illuminate.

Once the Write Mode has been entered, the Write Operation continues until the STOP button is pressed. Between the time when Write Mode begins and the time when the STOP button is pressed, all data from the microcomputer is written onto the tape. It is written from the data lines into a buffer that holds 128 eight-bit bytes (characters). When the buffer is full, the 128 data bytes are written onto the tape, constituting one data record. Records are written sequentially onto the tape in this manner to form tape files of data. When the STOP button is pressed, any unused character positions within the buffer are filled with NUL characters, and the last record of the file is written onto the tape followed by an End-of-File mark.

Skip Forward Operations

Skip Forward allows the 4923 to skip over one data file in the forward direction without transferring data. The operation may be ended earlier by pressing the STOP button. Skip Forward is implemented by a single momentary push of the FORWARD button. (Note that a momentary push is all that is required for the Skip Forward Operation. If the FORWARD button is held down, Fast Forward mode will begin, as described in the following paragraph.)

Fast Forward Operations

Fast Forward mode begins when the FORWARD button is pressed and held for about one second. When this occurs, the tape winds in the forward direction at 90 inches per second. This continues until the STOP button is pressed, or until the end of the usable tape area is reached, whichever occurs first.

Skip Reverse Operations

Skip Reverse allows the 4923 to back over one data file each time the REVERSE button is momentarily pressed. No data is transferred. The operation may be ended earlier by pressing the STOP button. (Note that a momentary push of the REVERSE button is all that is required for a Skip Reverse Operation. If the button is held down, Fast Reverse mode will begin, as described in the following paragraph.)

Fast Reverse (Rewind) Operations

Fast Reverse begins when the REVERSE button is pressed and held for about one second. When this occurs, the tape rewinds at 90 inches per second. Rewinding continues until the STOP button is pressed, or until the tape has rewound to the beginning of the usable tape area, whichever occurs first.

VII. EXAMPLE RECORDING SESSION

The following paragraphs describe a sample waveform recording session, using the various features of the microcomputer system.

First the oscilloscope, pulser, and antenna should be assembled and interconnected as dictated by the desired experiment and in accordance with Section II. The proper oscilloscope settings for the radar data can be determined while using the repetitive scan mode of the 7S12 sampling plug-in. After the computer connections are made as outlined in Section IV, the scan mode on the 7S12 should be set to external and the scan rate knob turned fully clockwise. When the computer is powered up the LED displays should read all zeroes indicating that the computer is ready and in the command loop. This may be further verified by pressing Key C on the key pad a number of times. The letter C should be displayed in the leftmost LED and an audible 'beep' should sound at each keypress.

If the number of averages to be taken is desired to be two instead of the default value of four, the key sequence 6-1 should be entered.

Pressing Key 7 then initiates sweeping of the oscilloscope in the tuneup mode. The radar waveform appears on the oscilloscope screen as it will be recorded and the numerics on the LED's indicate proper operation of the A/D converter. When ready to record a preliminary waveform press Key C to terminate tuneup mode and then Key Ø to record.

The sequence number of ØØ should be displayed in the center two LEDs. It is useful at this point to view the recorded waveform. This is done by entering Key sequence A-Ø-Ø, lowering the intensity of Beam 2 on the oscilloscope, and raising the beam 1 intensity. By viewing the waveform in this fashion the operator can decide if enough averages are being taken or if the high resolution (smoothing) feature of the 7S12 is needed.

After the appropriate measures have been taken and the preceeding sequence has been repeated, the memory may be cleared of these test waveforms by pressing Key B (memory dump) without enabling the cartridge tape recorder. The sequence number should then be reset (usually to zero) by entering key sequence 2-Ø-Ø.

The first two waveforms which should be recorded for any given trial are the top full scale and bottom full scale readings of the oscilloscope screen. These are used to calibrate the subsequent recorded waveforms in relation to the oscilloscope deflection factor. These straight line waveforms can be obtained by disconnecting the received signal cable from the S-5 plug-in and turning down the vertical sensitivity of the 7S12 to reduce noise. The 7S12 offset control is then used to position the trace to be recorded first at the top full scale line and then at the bottom full scale line.

After this detail has been taken care of, recording of waveforms can proceed by pressing key Ø for each recording. (See also Section III concerning data gathering techniques.) In between recordings the incoming received waveform may be viewed by pressing Key 7 (tuneup) or by switching the 7S12 unit to repetitive scan. If the repetitive scan feature is used it is essential that the 7S12 is returned to the external scan mode and the scan knob turned fully clockwise before another recording is made.

Once the desired number of waveforms have been obtained or the alarm goes off signifying full memory, the waveforms may be copied to the cartridge recorder. (Key E is used to silence the alarm.) The digital recorder may be put into the write mode by pressing in and holding in the WRITE button and momentarily pressing the RUN button. (Be sure that the BINARY button is depressed.) Pressing Key B on the microcomputer then causes the memory dump to occur. After this operation is complete, the STOP button on the recorder should be pressed. This causes an End-of-File mark to be written and advances the tape to the next position for writing.

An optional Read/Verify check may be made at this point. To do this press Key D on the microcomputer. Then press the REVERSE button momentarily on the recorder. When the tape stops press the RUN button. If the tape data is valid program control returns to the command loop and an audible beep is generated. Press the STOP button and then the FORWARD button on the recorder to position the tape for the next write. If the tape data is not valid, a continuous alarm is set off which can only be silenced by pressing Key E on the microcomputer. This done, back-up the tape to the beginning of this bad file by pressing STOP then REVERSE and try the Read Verify again (Key D) or repeat the memory dump procedure (Key B).

This process of recording and dumping waveforms may continue until all experiments are done or until there is no room on the tape. If after a memory dump (Key B) the indicator light over the tape recorder STOP button is lighted <u>before</u> you press the STOP button, the tape is out of room. This dump should be repeated on a fresh tape.

APPENDIX I

WAVEFORM RECORD FORMAT AND MICROCOMPUTER PROGRAM LISTING

Each waveform as recorded on the digital tape cartridge contains five preamble bytes, a variable number of data points (specified in the preamble) and three postamble bytes. For the general case of 256 data points, the waveform record size is 264 bytes. The significance of these bytes in the order read from the tape is charted below.

Byte 1: Header, always = 99 Hex

Byte 2: Header, always = 88 Hex

Byte 3: Number of waveform data bytes in record. Coded as follows.

- 1Ø Hex 16 data bytes
- 2Ø Hex 32 data bytes
- 4Ø Hex 64 data bytes
- 8Ø Hex 128 data bytes
- ØØ Hex 256 data bytes

Byte 4: Number of averages taken by system per data point. Coded as an eight bit integer.

Byte 5: Sequence number, used to identify the waveform. Range ØØ Hex to FF Hex.

Byte 6: First waveform data byte. Coded as an unsigned eight bit integer. ØØ Hex corresponds to the most 'negative' value and FF Hex to the most positive value.

Byte N+5: Last waveform data byte.

Byte N+6: Low order byte of the waveform data checksum. This 16 bit checksum is the negation of the sum of the N waveform data bytes.

Byte N+7: High order byte of waveform data checksum. When the 16 bit sum of Bytes 6 through N+5 is added to the 16 bit integer of bytes N+6 and N+7, zero should be the result.

Byte N+8: Trailer, always = FF Hex.

The following pages contain the program listing for the microcomputer data acquisition system. This program resides in 2708 Programmable Read Only Memories (PROM) in hardware slots ROMØ and ROM1 on the SDK-80 microcomputer board.

```
LOC  OBJ          SEQ         SOURCE STATEMENT

                      ;****************************
                      ;       THIS PROGRAM IS THE OSCILLOSCOPE VERSION
                      ;       OF THE SDK-85 PORTABLE MICROCOMPUTER SYSTEM.
                      ;       IT IS USED FOR GENERAL WAVEFORM MEASUREMENT AND
                      ;       OUTPUTS DATA TO TEKTRONIX 4924 DIGITAL RECORDER.
                      ;****************************
0000                  ROM0    EQU     0
0800                  ROM1    EQU     0800H
0000                  ROM2    EQU     8000H
0C00                  ROM3    EQU     0C000H
0001                  PERBIT  EQU     1
                      ;     *** 8279 KEYBOARD/DISPLAY INTERFACE ***
00CF                  KEYCMD  EQU     0CFH
00CE                  KEYBD   EQU     0CEH
00CE                  DISPLY  EQU     0CCH
00CF                  KETDSI  EQU     0FH
                      ;     *** 8255 I/O PORT (LEFT HAND SOCKET-A4) ***
00FF                  DATCNT  EQU     0FFH      ;CONTROL
00EC                  RCVDAT  EQU     0ECH      ;PORT A (DATA)
00ED                  RAMP    EQU     0EDH      ;PORT B
00EE                  MRKST   EQU     0FEH      ;PORT C
0009                  INTREQ  EQU     0
                      ;     *** 8255 I/O PORT (RIGHT HAND SOCKET-A5)
00F7                  P1CMND  EQU     0F7H
00F4                  P1A     EQU     0F4H
00F5                  P1B     EQU     0F5H
00F6                  P1C     EQU     0F6H
                      ;     ***
0040                  RDSTAT  EQU     40H
002F                  DATMSK  EQU     2FH
000E                  CLR7    EQU     0EH
000F                  SET7    EQU     0FH
0020                  STAREA  EQU     32
                      ;     *** PROGRAM RESIDES IN ROM0 ***
0000                          ORG     0
0000 F3               START:  DI
0001 31                       LXI     SP,SEQ+STAREA
0004 21                       LXI     H,0800H
0007 22                       SHLD    DBUFTP  ;INITIALIZE TOP OF BUFFER POINTER
                      ;     *** INITIALIZE DEFAULT SYSTEM PARAMETERS ***
                      ;       4 AVG/PT.     256 PTS/WAVEFORM
```

```
000A 3E0E            MVI     A,04E
000C 32  12          STA     NAVGS
000F AF              XRA     A
0010 320913          STA     NPTS
0013 210000          LXI     H,0
0016 221113          SHLD    STSFLG
               ;     *** INITIALIZE DATA BUFFER POINTERS
0019 212028          LXI     H,DATBFG
001C 220013          SHLD    STRPTR   ;STORE POINTER
               ;     *** INITIALIZE PARALLEL PORT A4 ***
001F 3EFF            MVI     A,0B1H
0021 D3EF            OUT     DATCNT   ;DATA CONTROL PORT
                                      ;(ROY) DATA + RA(P)
               ;     *** INITIALIZE PARALLEL PORT A5 ***
0023 CD0000          CALL    MINIT
               ;     *** INITIALIZE SEQUENCE NUMBER TO 0 ***
0026 AF              XRA     A
0027 321013          STA     SEQNO
002A 3E09            MVI     A,09     ;INTERRUPT ENABLE
002C D3EE            OUT     DATCNT   ;SET BIT PC4
               ;INITIALIZE PTS & NAVG TO DEFAULT VALUES
002E 210001          LXI     H,0100H  ;256 PTS/RECORD
0031 221113          SHLD    NPT
0034 C35B00          JMP     AROUND
               ;     ***************
               ;     DON'T FORGET 38H IS INTERRUPT LOCATION
               ;     ***************
0038                 ORG     38H
0038 C3EA01          JMP     INTRET   ;INTERRUPT VECTOR
               ;     *** INITIALIZE 8279 KEYBOARD + DISPLAY
003B 3E02      AROUND: MVI   A,2      ;2**2 AVGS
003D 321413          STA     NAVG
0040 3E3A            MVI     A,20H+20D        ;PRESCALE FOR CLOCK = 20
0042 D3CF            OUT     KBCNTR
0044 3E02            MVI     A,2      ;LEFT ENTRY,ENCODED 2-KEY ROLLOVER
0046 D3CF            OUT     KBCNTR
0048 3EC1      CCMDLP: MVI   A,0C1H   ;CLEAR ALL STATUS AND DISPLAY
004A D3CF            OUT     KBCNTR
004C DBCF      CLRWT: IN     KBCNTR   ;WAIT FOR CLEAR TO FINISH
004E 17              RAL
004F DA4C00          JC      CLRWT
               ;     *** COMMAND LOOP ***
```

```
0062 31A1[?]        CMDLP:  LXI     SP,SPO+STAREA
0065 CD[?]                  CALL    BEEP
0068 CD[?]                  CALL    KPIN    ;READ AND DISPLAY KEYPRESS
006B CD[?]                  CALL    DISP1
006E FE[?]                  CPI     0FH
0070 CA[?]                  JZ      START   ;RESTART
0073 FE[?]                  CPI     0DH
0075 CA[?]                  JZ      TPCHK   ;CHECK DATA TRANSMISSION
0078 FE[?]                  CPI     0BH
006A CA[?]                  JZ      TPWRT   ;DUMP MEMORY ONTO TAPE
006D FE[?]                  CPI     0AH
006F CA[?]                  JZ      WAVOUT  ;DISPLAY A WAVEFORM VIA D/A
0072 FE[?]                  CPI     8
0074 CA[?]                  JZ      RCMCH   ;BRANCH TO ANOTHER RCH
0077 FE07                   CPI     7
0079 CA[?]                  JZ      TUNEUP  ;DISPLAY DATA VALUES OF INTEREST
007C FE[?]                  CPI     6
007E CA[?]                  JZ      NAVRD   ;READ # OF AVERAGES/PT
0081 FE04                   CPI     4
0083 CA[?]                  JZ      SIZERD  ;READ # OF DATA PTS/WAVEFORM
0086 FE0[?]                 CPI     2
0088 CA[?]                  JZ      SEQSET  ;SET SEQUENCE NUMBER
008B FE01                   CPI     1
008D CA[?]                  JZ      PUTREW  ;RUN VIA ANTENNA PUSHBUTTON
0090 FE0[?]                 CPI     0
0092 CA[?]01                JZ      RUN
0095 C3[?]                  JMP     CMDLP
                    ;
                    ;       **********
                    ;
0098 CD[?]          RCMCH:  CALL    KPIN
009B CD[?]                  CALL    DISP1
009E FE0[?]                 CPI     0
00A0 CA[?]                  JZ      RCM0
00A3 FE0[?]                 CPI     2
00A5 CA[?]                  JZ      RCM2
00A8 FE0[?]                 CPI     3
00AA CA[?]                  JZ      RCM3
00AD C3[?]                  JMP     CMDLP
                    ;
                    ;       **********
                    ;
                    ;       *** FOR EACH INCOMING WAVEFORM COMPUTE AND
                    ;       *** DISPLAY AVG. VALUE, PEAK VALUE (ABOVE
                    ;       *** OR BELOW 1/2 FULL SCALE), AND POSITION
                    ;       *** OF THIS PEAK (0 TO FFH).
```

```
00B0 CD[illegible]          TUNELP: CALL    TUNE
00B3 3A1C13                         LDA     TPEAK    ;FETCH PEAK VALUE
00B6 0600                           MVI     B,0      ;SELECT LEFTMOST 2 DIGITS
00B8 CD[illegible]                  CALL    DPDISP   ;DISPLAY 2 CONSECUTIVE DIGITS
00BB 3A1713                         LDA     TTIME    ;FETCH TIME OF PEAK
00BE CDC302                         CALL    DSPFTC   ;DISPLAY IN CENTER 2 DIGITS
00C1 3A1613                         LDA     TAVG     ;FETCH AVG. VALUE
00C4 CDC302                         CALL    DSPFTC   ;DISPLAY IN RIGHTMOST 2 DIGITS
00C7 DB[illegible]                  IN      KBSTAT   ;FIFO STATUS WORD
00C9 E60F                           ANI     0FH      ;ANY KEYPRESSES ?
00CB CAB000                         JZ      TUNELP   ;IF NO STAY IN TUNELP MODE
00CE CDA502                         CALL    KIN      ;IF YES FETCH VALUE OF KEYPRESS
00D1 FE0C                           CPI     0CH
00D3 C2B000                         JNZ     TUNELP   ;JUMP IF NOT 'C'
00D6 C3[illegible]                  JMP     COMPLP   ;IF 'C' CLEAR DISPLAY &
                                                     ;ENTER COMPAND LOOP
00D9 AF                     TUNE:   XRA     A        ;INITIALIZE RAMP COUNT
00DA 32[illegible]13                STA     RMPSTR
00DD D3E0                           OUT     RAMP
00DF 67                             MOV     H,A
00E0 6F                             MOV     L,A
00E1 221613                         SHLD    TAVG
00E4 3E80                           MVI     A,80H    ;1/2 FULL SCALE
00E6 321C13                         STA     TPEAK
00E9 321[illegible]13               STA     TPKREG
00EC FB                     TLOOP:  EI
00ED 3A[illegible]12        TWAIT:  LDA     STSFLG   ;WORD READ LATELY
00F0 E640                           ANI     RDSTAT
00F2 CA[illegible]                  JZ      TWAIT    ;JUMP IF NO
00F5 F3                             DI
00F6 3A[illegible]13                LDA     STSFLG
00F9 E6BF                           ANI     NOT RDSTAT
00FB 32[illegible]13                STA     STSFLG   ;RESET READ FLAG
00FE 3A[illegible]13                LDA     RMPSTR   ;CHANGE RAMP NOW
0101 3C                             INR     A        ;TO ALLOW IT TO SETTLE
0102 D3E0                           OUT     RAMP
0104 3A[illegible]                  LDA     DAVG
0107 4F                             MOV     C,A
0108 3A1[illegible]13               LDA     TPEAK
010B B9                             CMP     C
010C D2[illegible]01                JNC     TMIN     ;JUMP IF NEW DATA NOT > TPEAK
010F 79                             MOV     A,C      ;NEW DATA IS GREATER THAN
```

```
0110 321714        STA    TPEAK    ;OLD DATA, SO UPDATE
0113 3A0A13        LDA    RMPSTR
0116 321713        STA    TIIME    ;SAVE   POSITION OF THE +PEAK
0119 3A1513  TMIN: LDA    TPKNEG
011C 09            CMP    C
011D DA2A01        JC     TAVER    ;JUMP IF NEW DATA POT < TPKNEG
0120 79            MOV    A,C      ;NEW DATA IS SMALLER
0121 321513        STA    TPKNEG   ;THAN OLD TPKNEG
0124 3A0A13        LDA    RMPSTR
0127 321813        STA    TIMNEG   ;SAVE POS. OF THE -PEAK
012A 0E00    TAVER: MVI   B,0      ;BC HAS DATA
012C 2A1A13        LHLD   TAVG
012F 09            DAD    B
0130 221A13        SHLD   TAVG     ;UPDATE SUM
0133 210A13        LXI    H,RMPSTR
0136 34            INR    M        ;INCREMENT RAMP COUNT
0137 3A0C13        LDA    NPTS     ;# OF PTS/WAVEFORM
013A BE            CMP    M        ;RAMP DONE ?
013B C2E000        JNZ    TLOOP    ;IF NOT CONTINUE DATA TAKING
013E 3A1513        LDA    TPKNEG   ;IS (+) OF (-) PEAK LARGER
0141 4F            MOV    C,A
0142 3A1413        LDA    TPEAK
0145 81            ADD    C
0146 DA5301        JC     FIXAVG   ;CARRY SET IF TPEAK IS LARGER
0149 79            MOV    A,C
014A 321413        STA    TPEAK    ;LET TPKNEG, TIMNEG
014D 3A1813        LDA    TIMNEG   ;BE DISPLAYED
0150 321713        STA    TIIME
0153 3A0C13  FIXAVG: LDA  NPTS     ;GET # OF PTS/WAVEFORM
0156 37            STC
0157 0EFF          MVI    C,-1
0159 0C     SHFCNT: INR   C
015A 1F            RAR
015B D25901        JNC    SHFCNT
015E 2A1A13        LHLD   TAVG     ;SUM OF DATA VALUES
0161 CD3203        CALL   HLSHFR   ;DIVIDE H,L BY
0164 221A13        SHLD   TAVG     ;# OF PTS/WAVEFORM
0167 C9            RET
                   ;
                   ;      *** RECORD A WAVEFORM
0168 2A0013  RUN:  LHLD   STRPTR
```

```
0168 CD0603            CALL    NEGHL
016B EB                XCHG
016C 2A0213            LHLD    BUFPTR
016F 19                DAD     D
        ;# OF PTS LEFT IN BUFFER TO HL
0170 EB                XCHG            ;MOV IN D+E
0171 2A1113            LHLD    NPT
0174 CD0603            CALL    NEGHL
0177 19                DAD     D       ;SUBTRACT # OF PTS/RECORD FROM
                                       ;# OF PTS LEFT IN BUFFER
0178 D2A203            JNC     TPDMP   ;IF NO SPACE LEFT, DUMP BUFFER ONTO TAPE
017B 210000            LXI     H,0     ;CLEAR CHECKSUM
017E 220F13            SHLD    CHKSUM
0181 3A0513    RUNST:  LDA     SEQNO   ;FETCH SEQUENCE NUMBER
0184 0602              MVI     B,2
0186 CD0C03            CALL    HPDISP  ;DISPLAY 2 DIGITS (CENTER)
0189 AF                XRA     A       ;RESET RAMP
018A 320C13            STA     RMPSTR
        ;PUSH PREAMBLE ONTO STACK
018D CDF602            CALL    PREAM
0190 CDE302            CALL    PEEP
0193 FB        RLOOP:  EI
0194 3A0C17    STWAI:  LDA     SYSFLG  ;WORD READ LATELY ?
0197 E640              ANI     RDSTAT
0199 CA9401            JZ      STWAT   ;JUMP IF NO
019C F3                DI
019D 3A0C13            LDA     SYSFLG
01A0 E6BF              ANI     NOT RDSTAT      ;CLEAR WORD FLAG
01A2 320C13            STA     SYSFLG
        ;STORE CURRENT DATA FROM RADAR SYSTEM
01A5 3A0A13            LDA     DAVG
01A8 CD1F03            CALL    DPUSH
        ;INCREMENT RAMP
01AB 3A0C13            LDA     RMPSTR
01AE 3C                INR     A
01AF D3EF              OUT     RAMP
01B1 320C13            STA     RMPSTR
01B4 4F                MOV     C,A
01B5 3A0913            LDA     NPTS    ;GET # OF PTS/WAVEFORM
01B8 B9                CMP     C       ;RAMP DONE ?
01B9 CAC001            JZ      RMPDUN  ;JUMP IF YES
01BC C39301            JMP     RLOOP
```

```
01C2 F3                 EMPDMP: DI
                        ;       PUSH POSTAMBLE ONTO STACK
                        ;       (CHECKSUM & DELAY)
01C3 2A[illegible]13            LHLD    CHKSUM
01C6 CD[illegible]03            CALL    REGHL
01C9 22[illegible]13            SHLD    CHKSUM
01CC 21[illegible]13            LXI     H,CHKSUM
01CF 0E02               GOTI:   MVI     C,2
01D1 CD[illegible]03            CALL    STRWRT
01D4 3EFF                       MVI     A,0FFH  ;ENTER RECORD GAP
01D6 CD[illegible]03            CALL    RPUSH
01D9 3A[illegible]13            LDA     SEGNO
01DC 3C                         INR     A
01DD 32[illegible]13            STA     SEGNO   ;UPDATE SEQUENCE NUMBER
01E0 2A[illegible]13            LHLD    STRPTR
01E3 22[illegible]13            SHLD    ENDPTR  ;STORE END OF DATA POINTER
01E6 CD[illegible]02            CALL    BEEP
01E9 C9                         RET             ;IF NOT GO BACK
                        ;       **********
                        ;INTERRUPT PROCESSING ROUTINE ADDS INCOMING DATA
                        ;TO THE TEMP BUFFER TAVG
                        ;       **********
01EA F3                 INTRPT: DI
01EB F5                         PUSH    PSW
01EC E5                         PUSH    H
01ED C5                         PUSH    B
01EE 3A[illegible]13            LDA     SYSFLG
01F1 47                         MOV     B,A
01F2 E6[illegible]              ANI     RDSTAT
01F4 C2[illegible]02            JNZ     GOUT    ;JMP IF LAST RESULT
                                                ;NOT SERVICED YET
01F7 78                         MOV     A,B
01F8 E6[illegible]              ANI     CNIMSK
01FA C2[illegible]02            JNZ     INPROC  ;JMP IF AVERAGING IN PROCESS
01FD 3A[illegible]13            LDA     NAVGS   ;LOAD COUNTER WITH # OF AVGS
0200 4F                         MOV     C,A
0201 78                         MOV     A,B
0202 E6[illegible]              ANI     NOT CNIMSK
0204 B1                         ORA     C
0205 32[illegible]13            STA     SYSFLG
                        ;RESET DAVG TO START A NEW COUNT
```

```
0208 210000              LXI     H,0
020B 22..13              SHLD    DAVG
                  ;ADD DATA TO DAVG
020E DBEC         INPROC: IN     RCVDAT
0210 0600                MVI     B,0
0212 4F                  MOV     C,A
0213 2A..13              LHLD    DAVG
0216 09                  DAD     B
0217 22..13              SHLD    DAVG
                  ;DECREMENT RCV DATA COUNTER
021A 3A..13              LDA     SYSFLG
021D 3D                  DCR     A
021E 32..13              STA     SYSFLG
0221 E62F                ANI     CNTMSK
0223 C25F02              JNZ     COUT     ;JMP IF AVERAGING
                                          ;PROCESS NOT COMPLETED.
                  ;AVERAGING PROCESS COMPLETED, DIVIDE DAVG BY # OF AVG'S
0226 3A1513              LDA     NAVG
0229 4F                  MOV     C,A
022A 2A..13              LHLD    DAVG
022D B7                  ORA     A
022E C43..3              CNZ     HLSHFR
0231 22..13              SHLD    DAVG
                  ;UPDATE CHECKSUM
0234 CD.F03              CALL    CHEKSM
                  ;SET DATA READY FLAG
0237 3A..13              LDA     SYSFLG
023A F64.                ORI     RDSTAT
023C 32..13              STA     SYSFLG
023F E1           COUT:  POP     H
0240 C1                  POP     B
0241 F1                  POP     PSW
0242 FB                  EI
0243 C9                  RET
                  ;
                  ;      *** READ NO. OF AVERAGES TO BE TAKEN
                  ;      *** (1, 2, 4, 8, 16, OR 32)
0244 CD.F02       NAVRD: CALL    KBIN
0247 FE..                CPI     6
0249 D24402              JNC     NAVRD    ;LOOP IF INVALID
024C 321513              STA     NAVG
```

```
024F 3C                      INR     A
0250 4F                      MOV     C,A
0251 3E80                    MVI     A,80H
0253 07           AVNO:      RLC                 ;CHANGE 0,1,2,3,4,5
0254 0D                      DCR     C
0255 C25302                  JNZ     AVNO
0258 32  13                  STA     NAVGS       ;TO 1,2,4,8,16,32
025B C34  0                  JMP     COMPLE
                  ;          **********
                  ;          SET LENGTH OF WAVEFORM TO 256,128,64,32, OR 16
                  ;          **********
025E CD  0        SIZERD:    CALL    KBIN
0261 FE05                    CPI     5
0263 D25E02                  JNC     SIZERD      ;JUMP IF INVALID
0266 3C                      INR     A
0267 4F                      MOV     C,A
0268 AF                      XRA     A           ;ZERO OUT CARRY BIT
0269 3E  3                   MVI     A,8
026B 07           SIZNO:     RLC
026C 0D                      DCR     C
026D C26B02                  JNZ     SIZNO
0270 4F                      MOV     C,A
0271 E60F                    ANI     0FH
0273 321  1                  STA     NPT+1
0276 79                      MOV     A,C
0277 E6F0                    ANI     0F0H
0279 C6  A                   ADI     P           ;ADD PREAMBLE + POSTAMBLE BYTES TO TOTAL
027B 32111                   STA     NPT
027E E6F0                    ANI     0F0H
0280 320  1                  STA     NPTS
0283 C34  0                  JMP     COMPLE
                  ;          **********
                  ;          INITIATE RECORDING WITH ANTENNA HANDLE PUSHBUTTON
                  ;          **********
0286 DBFE         PUTRUN:    IN      MRKST       ;READ BUTTON (MARK BIT)
0288 E601                    ANI     MRKBIT      ;IF WHEN BUTTON PRESSED
028A CCF                     CZ      RUN         ;RECORD A WAVEFORM SEQUENCE
028D DB0F                    IN      KBGETN      ;KEY PRESSED LATELY ?
028F E60F                    ANI     KBINST
0291 CA8602                  JZ      PUTRUN      ;JUMP IF NO
0294 CD  02                  CALL    KIN         ;READ KEYPAD
```

```
0297 FE ..        CPI     0CH       ;WAS IT 'C'
0299 C2....       JNZ     KEYIN     ;IF NO LOOK @ BUTTON SOME MORE
029C CA....       JZ      CYCLE     ;IF YES, LOOP !
              ;   **********
              ;   READ DIGIT FROM 16 KEY KEYPAD
              ;   THE KEYBOARD INTERFACE HAS AN INTERNAL FIFO.
029F DB..   KEYIN:  IN    KBCNTR    ;FIFO STATUS WORD
02A1 E6..         ANI     ..ST
02A3 CA....       JZ      KEYIN     ;LOOP IF FIFO EMPTY
02A6 CD....       CALL    BEEP
02A9 3E4.   FIFO: MVI     A,4..     ;SPECIFY FIFO READ
02AB D3..         OUT     KBCNTR
02AD DB..         IN      KEYDAT
02AF E6.F         ANI     3FH       ;CHANGE SCAN/RETURN CODE
02B1 ..           ..C               ;INTO HEX VALUE
02B2 C9           RET
              ;   DISPLAY VALUE IN LEFTMOST LED
02B3 F5     DISP1:  PUSH  PSW
02B4 3E..         MVI     A,30H     ;SELECT LEFTMOST DIGIT
02B6 D3..         OUT     KBCNTR
02B8 F1           POP     PSW
02B9 D3..         OUT     DISPLY
02BB C9           RET
              ;   **********
              ;   DISPLAY 2 HEX DIGITS FROM 'A' REG IN LED'S
              ;   STARTING WITH CELL SPECIFIED BY 'B' REG.
              ;   **********
02BC 4F     UPDISP: MOV   C,A
02BD 3E..         MVI     A,90H     ;WRITE DISPLAY RAM
02BF 80           ADD     B         ;0,1,2,3,4,5
02C0 D3..         OUT     KBCNTR
02C2 79     DISP2:  MOV   A,C
            ;ENTER HERE TO DISPLAY AT NEXT
            ;TWO RAM ADDRESSES.
02C3 4F     DSPLIC: MOV   C,A
02C4 1F           RAR
02C5 1F           RAR
02C6 1F           RAR
02C7 1F           RAR
02C8 E6..         ANI     0FH
02CA D3..         OUT     DISPLY    ;WRITE HIGH ORDER DIGIT
02CC 79           MOV     A,C
```

```
02DC E60F              ANI     0FH
02DE D3FF              OUT     DISPLY  ;WRITE LOW ORDER DIGIT
02E1 C9                RET
                ;
                ;      READ TWO DIGITS FROM KEYBOARD & PACK INTO 'A' REG
                ;
02E2 CD9F02     TWOIN: CALL    KPIN
02E5 47                MOV     B,A     ;SAVE 1ST (HI ORDER) DIGIT
02E6 07                RLC
02E7 07                RLC
02E8 07                RLC
02E9 07                RLC
02EA D3FF              OUT     DISPLY  ;ZERO 2ND DIGIT
02EC 4F                MOV     C,A
02ED CD9F02            CALL    KPIN
02E0 B1                ORA     C
02E1 F5                PUSH    PSW
02E2 78                MOV     A,B     ;RETRIEVE 1ST (HI ORDER) DIGIT
02E3 CD8302            CALL    DISP1   ;PUT INTO LEFTMOST LED
02E6 F1                POP     PSW
02E7 D3FF              OUT     DISPLY  ;2ND DIGIT INTO 2ND LED
02E9 C9                RET
                ;
                ;SEQSET ALLOWS THE SEQUENCE # TO BE SPECIFIED.
                ;THE SEQUENCE # IS INCREMENTED EVERY TIME 'RUN'
                ;SEQUENCE IS EXECUTED.
                ;
02EA CDD202     SEQSET: CALL   TWOIN
02ED 3211 13           STA     SEQNO
02F0 C34 00            JMP     CCMDLP
                ;
                ;TRIGGER ALARM SO THAT IT 'BEEPS'
                ;BEEPER CONTROLED BY BIT PC7
                ;
02F3 F5         BEEP:  PUSH    PSW
02F4 3E0F              MVI     A,CLR7
02F6 D3FF              OUT     DATCNT
02F8 3E0F              MVI     A,SET7
02FA D3FF              OUT     DATCNT
02FC F1                POP     PSW
```

```
02FE C9                  RET
               ;
               ;
               ;
02FF 3E..      PREAMB:   MVI     A,0EH
0301 CD....              CALL    DPUSH
0304 3E..                MVI     A,..
0306 CD....              CALL    DPUSH
0309 3A..1.              LDA     DPTS      ;# OF DATA PTS X # OF AVG'SS
030C CD1...              CALL    DPUSH
030F 3A..1.              LDA     NAVGS
0311 CD1...              CALL    DPUSH
0314 3A..1.              LDA     SEGNO
0317 CD1...              CALL    DPUSH
031A C9                  RET
               ;
               ;PUSH BYTE ONTO THE STACK
               ;
031B E5        DPUSH:    PUSH    H
031C C5                  PUSH    B
031D 2A..1.              LHLD    STKPTR
0320 77                  MOV     M,A
0321 23                  INX     H
0322 22..1.              SHLD    STKPTR
0325 C1                  POP     B
0326 E1                  POP     H
0327 C9                  RET
               ;
               ;         PUSH 'C' CONSECUTIVE WORDS ONTO DATA STACK
               ;
0328 7E        STKWRT:   MOV     A,M
0329 CD1...              CALL    DPUSH
032C 23                  INX     H
032D 0D                  DCR     C
032E C22...              JNZ     STKWRT
0331 C9                  RET
               ;
               ;         SHIFT H,L RIGHT 'C' TIMES
               ;
0332 B7        HLSHFR:   ORA     A         ;CLEAR CARRY
0333 7C                  MOV     A,H
0334 1F                  RAR
```

```
0535 67                  MOV     H,A
0536 7D                  MOV     A,L
0537 1F                  RAR
0538 6F                  MOV     L,A
0539 0D                  DCR     C
053A C23205              JNZ     FLSHER
053D C9                  RET
                 ;
                 ;       ROUTINE ADDS CONTENTS OF HL TO CHKSUM
                 ;
053E EB          CHEKSM: XCHG
053F E5                  PUSH    H
0540 2A0E13              LHLD    CHKSUM
0543 19                  DAD     D
0544 220E13              SHLD    CHKSUM
0547 E1                  POP     H
0548 EB                  XCHG
0549 C9                  RET
                 ;
                 ;       NEGATE H,L REGISTER
                 ;
054A 7C          NEGHL:  MOV     A,H
054B 2F                  CMA
054C 67                  MOV     H,A
054D 7D                  MOV     A,L
054E 2F                  CMA
054F 6F                  MOV     L,A
0550 23                  INX     H
0551 C9                  RET
                 ;
                 ;
0552 3E0E        TPDMP:  MVI     A,CLR7
0554 D3EF                OUT     DATCNT  ;SET OFF ALARM UNTIL
                                         ;AN 'E' IS PRESSED.
0556 DBDF        TPDMP1: IN      KBCNTR  ;KEY PRESSED LATELY?
0558 E6CE                ANI     KBINST
055A CA5605              JZ      TPDMP1  ;IF NO CONTINUE ALARM.
055D CD7905              CALL    KIN
0560 FE0E                CPI     0EH
0562 C25605              JNZ     TPDMP1
```

```
0365 3E?F              MVI     A,SET7
0367 D3??              OUT     PATCNT   ;TURN OFF ALSEP
0369 C3????            JMP     CMDLP    ;GO BACK TO COMMAND LOOP
                ;
                ;       **** CONTINUOUSLY OUTPUT WAVEFORM TO D/A FOR
                ;       **** VIEWING ON A MONITOR SCOPE.
                ;
036C CD????     WAVOUT: CALL    TWOIN
036F 32??13            STA     SGNO
0372 21??2?            LXI     H,DBUFO
0375 11????            LXI     D,DBUF4
0378 19         WVOUT1: DAD     D        ;GET POSITION OF SEGNO.
0379 22??13            SHLD    DAVG     ;SAVE IT.
037C CD??0?            CALL    BEGIN
037F EB                XCHG
0380 2A??13            LHLD    STRPTR
0383 19                DAD     D        ;SEE IF WE HAVE GONE
                                        ;PAST GOOD DATA.
0384 D2????            JNC     CMDLP    ;JUMP IF YES
0387 2A??1?            LHLD    DAVG
038A 4E                MOV     C,M      ;FETCH  SEG NO.
038B 3A??13            LDA     SGNO
038E B9                CMP     C
038F 2A1113            LHLD    NPT
0392 EB                XCHG
0393 2A??13            LHLD    DAVG
0396 C27?03            JNZ     WVOUT1   ;IF NOT TRY NEXT RECORD
0399 2A??13     WVOUT2: LHLD    DAVG
039C 23                INX     H        ;ADD ONE FOR START OF DATA
039D AF                XRA     A
                ;       *  OUTPUT LOW + BOTTOM FULL SCALE
                ;       *  FOR SCOPE SYNCING PURPOSES!
039E D3??              OUT     RAMP
03A0 CD??0?            CALL    DELY
03A3 2F                CMA
03A4 D3??              OUT     RAMP
03A6 3A1113            LDA     NPT
03A9 DE0?              SBI     ?
03AB 4F                MOV     C,A
03AC 7E         WVLP:  MOV     A,M
03AD CD??0?            CALL    DELY
03B0 D3??              OUT     RAMP
```

```
05E2 2?                     INX     H
05E3 0?                     POP     B
05E4 C2????                 JNZ     WVLP
                    ;
05E7 ????                   ?       KBCLTR  ;KEY PRESSED LATELY?
05E? E6??                   ANI     KMASST
05E? C?????                 JZ      WVOUT2
05EE C????                  CALL    KIN     ;YES
05F1 FE??                   CPI     ??H     ;WAS IT A ??? ?
05F3 CA????                 JZ      CCMDLP  ;IF SO BACK TO COMMAND LOOP
05F6 C3????                 JMP     WVOUT2  ;IF NOT CONTINUE OUTPUTTING
                    ;
                    ;       **** D/A HAS 20 MICROSECOND SETTLING TIME
                    ;       **** CALL=?.? , DELY=15.5 MICROSECONDS
                    ;
05C9 C5             DELY:   PUSH    B
05CA C1                     POP     B
05CB C9                     RET
                    ;
                    ;       *** INITIALIZE 8255 FOR TAPE WRITE
05CC 3E??           WINIT:  MVI     A,8AH   ;PORT A - OUTPUT
                                            ;UPPER C - INPUT
                                            ;LOWER C - OUTPUT
05CE D3F7                   OUT     0F7H
05D0 3E07                   MVI     A,07H   ;ENABLE   HIGH
                                            ;MTSTROBE HIGH
                                            ;READY    HIGH
                                            ;PC3      LOW
05D2 D3F?                   OUT     0F?H
05D4 C9                     RET
                    ;
                    ;       *** DUMP MEMORY ONTO CARTRIDGE RECORDER
05D5 CDCC05         TPWRT:  CALL    WINIT   ;INITIALIZE 8255 FOR
                                            ;WRITING DATA ONTO TAPE
05D8 21??2?                 LXI     H,0??F0 ;BEG OF DATA
05DB 7E             TPWRTO: MOV     A,M     ;FETCH DATA
05DC D3F4                   OUT     0F4H    ;SEND IT (PORT A)
05DE 3E02                   MVI     A,2     ;RESET BIT PC1 (MTSTROBE)
05E0 D3F7                   OUT     0F7H
05E2 3E03                   MVI     A,3     ;SET    BIT PC1 (MTSTROBE)
05E4 D3F7                   OUT     0F7H
```

```
03E6 DBF6     TPART1: IN      0F6H     ;CHECK BUSY FLAG (BIT 4)
03E8 E610             ANI     10H
03EA CA??03           JZ      TPART1   ;BUSY IF BIT 4=0
03ED 23               INX     H
03EE E5               PUSH    H
03EF CD4703           CALL    MEGHL
03F2 EB               XCHG
03F3 2A??1?           LHLD    ENDPTR
03F6 19               DAD     D        ;HAVE WE REACHED THE
                                       ;END OF THE DATA YET?
03F7 E1               POP     H
03F8 D2??03           JC      TPART1   ;KEEP GOING IF NOT
03FB 210020           LXI     H,BUFFER
03FE 22??1?           SHLD    STRTPR   ;RESET STORAGE POINTER
0401 C3??0?           JMP     COMDMD   ;BACK TO COMMAND MODE
                      ;
                      ;       *** PERFORM READ/VERIFY OF TAPE
                      ;       *** DATA AGAINST MEMORY.
0404 3E9?     TPCHK:  MVI     A,9?H    ;PORT A = INPUT
                                       ;UPPER C =INPUT
                                       ;LOWER C OUTPUT
0406 D3F7             OUT     0F7H
0408 210020           LXI     H,BUFFER ;BEG OF DATA
040B 3E0?     TPCHK?: MVI     A,02H    ;ENABLE    LCG
040D D3F6             OUT     0F6H     ;MISTROBE HIGH
                                       ;READY     LOW
                                       ;FC4       LOW
040F DBF6     TPCHK1: IN      0F6H
0411 E620             ANI     20H      ;SEE IF DATA IS GOOD YET
0413 CA0F04           JZ      TPCHK1   ;IF NOT KEEP TRYING
0416 3E0E             MVI     A,0EH    ;PUT DRIVE READY + FC5 HIGH
0418 D3F6             OUT     0F6H     ;TO STOP DATA INPUT
041A DBF4             IN      0F4H     ;FOR READ DATA
041C 4E               MOV     C,M      ;FETCH DATA FROM MEMORY
041D B9               CMP     C        ;ARE THEY EQUAL
041E C2520?           CNZ     TPCM?    ;IF NOT SET OFF ALARM TO
                                       ;NOTIFY OPERATOR OF ERROR
0421 23               INX     H
0422 E5               PUSH    H
0423 CD4A0?           CALL    MEGHL
0426 EB               XCHG
```

```
0427 2A0613          LHLD    ENDPTR   ;HAVE WE REACHED THE
                                      ;END OF THE DATA YET?
042A 19              DAD     D
042B E1              POP     H
042C DA0A04          JC      TPCHKO   ;KEEP GOING IF NOT
042F 210020          LXI     H,DBUFO
0432 220013          SHLD    STRPTR   ;RESET STORAGE POINTER
0435 C30000          JMP     READLP
                  ;
                  ;
                  ;      ******************************
1300                     ORG     1300H    ;BEG. OF ONBOARD RAM
1300              STRPTR: DS     2
1302              DBUFTP: DS     2
1304              ENDPTR: DS     2
1306              DAVG:   DS     2
1308              RMPSTR: DS     1
1309              NPTS:   DS     2
130B              DAVGS:  DS     1
130C              SYSFLG: DS     1
130D              SQNO:   DS     1
130E              CHKSUM: DS     2
1310              SEQNO:  DS     1
1311              NPT:    DS     2
1313              NAVG:   DS     1
1314              TAVG:   DS     2
1316              IFFAK:  DS     1
1317              ITTME:  DS     1
1318              TPKNEG: DS     1
1319              TIMNEG: DS     1
                  ;  STACK AREA
131A              SP0:    DS     STAREA
                  ;      BEGINNING OF DATA BUFFER
2000                     ORG     2000H
                  DBUFO:
0000                     END     START
```

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